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1996-97 School Year

Physics 30 Information Bulletin

Diploma Examinations Program

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This document was written primarily for:

Students	
Teachers	✓ Physics 30 teachers
Administrators	✓
Parents	
General Audience	
Others	

Distribution: Superintendents of Schools • School Principals and Teachers • The Alberta Teachers' Association • Alberta Education • General Public upon Request

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Purpose of the Bulletin

The purpose of this bulletin is to provide students and teachers of Physics 30 with information about the diploma examinations scheduled for 1997.

We encourage teachers to share the contents of this bulletin with students and to review the scoring criteria with them.

If you have requests, questions, or comments about the contents of this bulletin, please contact:

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Important Dates in 1997

Administration of the Physics 30 Diploma Examination

1997 Administrations	*Time**
Wednesday, January 29	1:00–3:30 P.M.
Thursday, June 26	1:00–3:30 P.M.
Monday, August 18	1:00–3:30 P.M.

* The diploma examination is designed for a writing time of 2.5 h. Students may have an additional 0.5 h to complete the examination.

Please consult the *General Information Bulletin, Diploma Examinations Program*, for a complete schedule for all subject areas.

Scoring of the Examination

1997 Administrations	*Scoring Dates***
January	February 11, 12 (Head Markers) February 13 to 15
June	July 5, 6 (Head Markers) July 7 to 10
August	August 22

* * Dates are tentative and will be confirmed by telephone with markers.

Notes of Interest

Information About Markers

The written-response questions of the Physics 30 Diploma Examinations are marked by Physics 30 teachers selected from those who have been recommended as markers to the Student Evaluation Branch by their superintendents. To qualify for recommendation, a teacher must have taught the complete Physics 30 course twice, be teaching the course in the current school year, and have an Alberta or Northwest Territories Permanent Professional Teaching Certificate.

Often, more teachers are recommended as markers by superintendents than are required by the Student Evaluation Branch for any one marking session. The following criteria are considered when markers are selected for a particular marking session:

- experience as a marker (experienced markers and first-time markers are included)
- regional representation (by zone, jurisdiction, and school)
- student population (proportional representation)

We particularly need teachers who can mark examinations written in French.

Teachers who wish to be recommended as markers for the January 1997 examination should contact their superintendents by September 27, 1996. Teachers who wish to be recommended as markers for the June and August 1996 examinations should contact their superintendents by **February 28, 1997**.

Item Writing and Field Testing

As the need arises for teachers to participate in field testing and item writing, letters are sent to superintendents requesting their nominations. Item writing takes place throughout the year and is a vital component of the diploma exam program. Field testing provides students and teachers with the opportunity to become familiar with the nature of questions they will encounter on future diploma exams. Only teachers who have been nominated by their superintendents are eligible to participate in these activities. Therefore, it is essential that **teachers who are interested in these activities should let their superintendents know by September 12, 1996.**

Reports

After each January and June administration of the Physics 30 diploma examination, copies of the *Examiners' Report* for that particular administration are sent to teachers in all senior high schools in Alberta. The report contains provincial results along with commments about student performace on the examination. Examiners' reports are designed for teacher use. If we can make these reports more useful to you, please let us know.

School and Jurisdiction Statistical Reports are sent to each superintendent and senior high school principal after each January and June administration of the Physics 30 diploma examination. These reports provide detailed information on how well the students in their school district and school, respectively, did on the Physics 30 diploma examination. Teachers may use these data to reflect on the areas of the program where their students did well and those areas where student performance was poor.

Each year, the Student Evaluation Branch produces the *Annual Report, Diploma Examinations Program*. This report contains information about the results achieved by all students who wrote diploma examinations in the preceding school year. It also contains special studies on topics of interest. The first annual report (1989–90 school year) contains a study comparing achievement in various diploma courses. The second report (1990–91 school year) contains a study comparing the achievement of students who repeat diploma examination courses and rewrite diploma examinations with their achievement the first time and with the achievement of students who write only once. The third report (1991–92 school year) contains a study of participation rates in diploma examination courses. The fourth report (1992–93 school year) contains a study of English 30 students' application of conventions of language. The fifth report (1993–94 school year) presents a comparison of provincial participation rates in diploma examination subjects for the school years 1991–92, 1992–93, and 1993–94. The sixth report (1994–95 school year) examines declining enrollment of Grade 12 students. Each of these special studies will be of interest to teachers who are involved in interpreting diploma examinations results of their students.

Additional copies are available from the student Evaluation Branch. Phone: 427-0010 FAX: 403-422-4200
To call toll-free from outside of Edmonton, dial 310-000.

As of the 1995-96 school year, this report is available on the Internet at Alberta Education's Web Site (http://ednet.edu.gov.ab.ca).

Inservices and Presentations

On a limited basis and subject to budget constraints, Student Evaluation Branch staff is available to provide inservices or presentations related to diploma examinations or the interpretation of diploma examination results.

Student Use of Scientific Calculators

Examinations are constructed to ensure that the use of particular scientific calculators neither advantages nor disadvantages individual students. Students are expected to provide their own scientific calculators.

NEW

Refer to Appendix A for the policy statement on the use of scientific calculators on diploma examinations. Students should be made aware of this policy as early as possible in the school term to ensure they are able to use the scientific calculator of their choice when writing examinations. It is important to clarify with students exactly what they are allowed to have stored in their calculator memories.

Students should also be made aware of the Examination Rules, Grade 12 Diploma Examinations (see the *General Information Bulletin*).

Guide for Students

NEW

A publication written for students called *Students First: A Guide for Students Preparing to Write the Physics 30 Diploma Examination* is available in each senior high school. See your principal or department head for the black line master. This publication contains suggestions for exam preparation and exam writing suggestions. The Student Evaluation Branch highly recommends that students and teachers examine this document early in the term to prepare for the Physics 30 Examination. Parents will also find this to be a useful publication.

Data Resources for Students

NEW

The Physics 30 diploma examinations contain tear-out data pages. Students should remove the tear-out data pages from the exams at the beginning of the writing session. These pages do not have to be returned with the exam booklets and answer sheets. The data presented are generic for all of the Physics 30 diploma exams provided during a school year; therefore, only some of the data are useful for any particular exam. The format of the data sheet has been changed. In addition a periodic table has been provided for student reference. See pages 38 to 40 for samples of the periodic chart and new data sheet format.

Student Requests for Rescores

Students may request a rescoring of their diploma examinations. Before applying for a rescoring, students should check their Diploma Examination Results Statement to find out the distribution of marks. The mark on the machine-scored questions is not likely to change as a result of a rescore, but the written-response mark could change slightly. Students should remember that the rescored mark will be the final mark whether it *increases* or *decreases*.

Students who decide to have an examinaton rescored must ensure that their application is received before the deadline specified on the results statement. The fee for rescoring each examination is $26.75, which includes GST. If a diploma examination mark is increased by 5% or more as a result of rescoring, the fee is refunded.

Student Requests for Rewriting

Students may rewrite a diploma examination in any regularly scheduled administration. Students must apply to the Student Evaluation Branch by November 15, 1996, and April 15, 1997, to be eligible to write the January and June diploma examinations. The fee for rewriting each examination is $26.75, which includes GST. (For more details, see the *General Information Bulletin*.)

Physics 30 Information

Objectives of the Course

Physics 30 is an academic course intended to further students' understanding and application of fundamental concepts and skills. The focus is on understanding the physics principles behind the natural events they experience and the technology they use in their daily lives. The course encourages enthusiasm for the scientific enterprise and develops positive attitudes about physics as an interesting human activity with personal meaning. It develops the knowledge, skills, and attitudes to help students become capable of, and committed to, setting goals, making informed choices, and acting in ways that will improve their own lives and life in their communities.

To develop the required knowledge, skills, and attitudes in Physics 30, it is necessary that students successfully complete Science 10 and Physics 20.

Standards

Students who achieve an *acceptable* standard but not the standard of excellence in Physics 30 received a final mark of 50% or higher. They have gained new skills and knowledge in physics but may encounter difficulties if they choose to enroll in post-secondary physics courses. These students can state and solve problems that can be related quickly to an equation on the data sheets. Their laboratory skills are limited to following explicit directions and to using laboratory data to verify known physics information. These students are capable of defining and calculating quantities such as one-dimensional momentum; kinetic and potential energies; electric force and the force due to gravity; current, potential difference, and resistance in simple series and parallel circuits; variables in the relationship between the primary and secondary coils of a transformer; speed, wavelength, and frequency of electromagnetic waves; charge-to-mass ratios; and the photoelectric work function. They tend to use item-specific methods in their problem solving and rarely apply the major generalizations of physics such as conservation laws of charge, momentum, and energy. When explaining the connections between science, technology, and society, these students tend to use examples provided from textbooks and have difficulty connecting physics to real-life scenarios beyond the classroom.

Students who achieve a standard of *excellence* in Physics 30 receive a final mark of 80% or higher. They have demonstrated their ability and interest in both mathematics and physics and feel confident about their scientific abilities. These students should encounter little difficulty in post-secondary physics programs and should be encouraged to pursue careers in which they will utilize their talents in physics. Students who achieve a standard of *excellence* show flexibility and creativity when solving problems, and minor changes in problem format do not cause them major difficulties. They seek general methods to solve problems and are not afraid to use conservation laws. They transfer knowledge from one area of physics to another and can express their answers in clear and concise terms. In addition, these students can connect their understanding of physics to real-world situations that include technological applications and implications beyond the classroom setting. In the laboratory, students who achieve a standard of *excellence* can cope with data that are less than perfect or with instructions that are incomplete. These students are capable of defining and calculating quantities such as two-dimensional momentum; current and voltage, using Kirchoff's rules; resistance in series and parallel circuits; the motion of an electric charge in a magnetic field; and variables in the Balmer equation.

Examination Specifications

Each Physics 30 Diploma Examination is constructed as closely as possible to the preceding specifications. Adjustments in the emphasis may be necessary because the exam includes written-response questions and/or machine-scored questions that cover more than one general learner expectation. Questions on the diploma examination will require students to demonstrate knowledge of physics concepts and apply skills in a context that supports making STS connections.

The design supports the integration of all Physics 30 general learner expectations as outlined in the *Physics 20–30 Program of Studies, Interim, for Senior High Schools*. As a result, the exam is not necessarily arranged sequentially by units but instead is built around scenarios or contexts that support STS connections.

Examination Specifications (continued)

The 1997 Physics 30 diploma examinations are constructed to place the following approximate emphases on the Physics 30 Course General Learner Expections.

Knowledge	***Emphasis***
The student can:	
• compare and contrast scalar and vector quantities and fields; apply the concept of field to quantitatively explain, in terms of their source, direction, and intensity, the gravitational, electrical, and magnetic effects on objects and systems	10–20%
• describe quantitatively, analyze, and predict the behaviour and physical interactions of objects that may be in gravitational, electric, and/or magnetic fields, using the principles of kinematics, dynamics, conservation of energy, momentum, and electric charge, in addition to electrostatics and electromagnetism; apply these principles to atomic theory and other applications	35–45%
• explain quantitatively, analyze, and predict the motor/generator effect; describe quantitatively, analyze, and predict the functioning of simple resistive direct current circuits, using Ohm's law and Kirchoff's rules; explain the design, function, and technological applications of simple electric motors, generators, meters, transformers, and other simple electromagnetic devices	10–20%
• explain quantitatively the characteristics and behaviours of electromagnetic waves, and algebraically solve problems using the relationship among speed, wavelength, frequency, and energy, and apply these principles with conservation laws to the atomic theory and other applications	25–35%

Skills	***Emphasis***
The student can:	20–40%
• design, interpret, explain, analyze, and evaluate investigations	
• organize data into tables, graphs, and diagrams and predict relationships	
• interpret, explain, analyze, and evaluate data to infer relationships	
• use appropriate scientific terminology and mathematical language to communicate and explain scientific concepts	

Connections Among Science, Technology, and Society (STS)	***Emphasis***
The student can:	40–60%
• apply cause-and-effect reasoning to formulate relationships in which scientific evidence shapes or refutes a theory, and explain the limitations of science and technology in answering all questions and solving all problems	
• describe and evaluate the design and function of technological solutions to theoretical and practical problems using scientific principles and theories, and relate the ways in which science and technology advance one another	
• evaluate from a variety of perspectives how science and technology are influenced and supported by society, and assess the ability of society to interact responsibly with the environment	
• apply the skills and knowledge acquired in Physics 30 to everyday life and to related and new concepts in post-secondary studies of physics	

Examination Design

The design of the 1997 Physics 30 diploma examinations is as follows:

Question Format	*Number of Questions*	*Percent Emphasis*
Multiple Choice	37	53
Numerical Response	12	17
Written Response	2	30

The Physics 30 Diploma Examination uses some linked questions in the multiple-choice and numerical-response sections. Prior to 1996, all multiple-choice and numerical-response questions were developed and scored independently of one another. Now, with the development of more than one question based on the same block of information, a numerical answer from one question may be necessary to complete the calculations in the next question. If students answer the first question incorrectly but use that answer correctly to answer the second question, they will receive full marks for the second question.

To illustrate by example, numerical response 1, 2, and 3 on the January 1996 Physics 30 Diploma Examination are of this type. In numerical-response question 1, the student is required to generate a numerical response for the estimated speed of the vehicle before the brakes are applied. Numerical-response questions 2 and 3 require the student to then **use the recorded answer** to numerical-response question 1 to calculate heat energy and impulse. If the student answers numerical-response question 1 incorrectly but then uses **that recorded value** correctly to calculate answers for numerical-response questions 2 and 3, the student's response to these two questions will be marked correct.

A further example, from the January 1995 Physics 30 diploma examination, linked multiple-choice question 13 and numerical-response question 6. Students could use their recorded answer from MC question 13 to answer NR question 6 correctly, even though their answer to multiple-choice question 13 may have been incorrect.

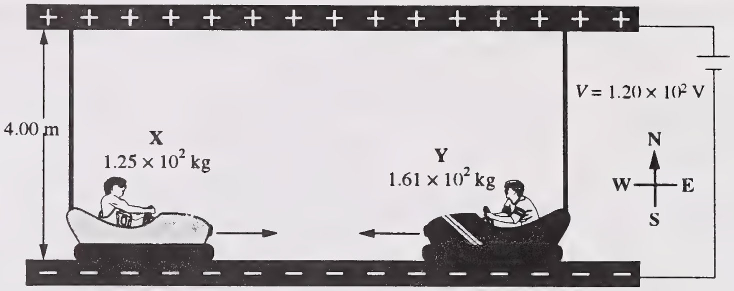
These variations in answers can be accommodated by the programming designed for electronic scoring.

Numerical-Response Formats

NEW

Several formats for recording numerical-response answers are shown on the following pages. Teachers and students should become familiar and comfortable with these formats before writing the 1997 Physics 30 Diploma Examination.

Use the following information to answer the next question.



Bumper cars operate on electricity. The more the accelerator pedal is pressed, the more current flows in the system, thus the faster the car travels. Car **X** and car **Y** are going to collide head-on. Car **X** is travelling at a constant velocity of 2.25 m/s to the east and car **Y** is travelling at a constant velocity of 1.30 m/s to the west.

Numerical Response

1. The total mechanical energy of the bumper cars described, expressed in scientific notation, is $b \times 10^w$ J. The value of b is __________.
(Round and record your answer to three digits.)

Answer: $\boxed{4}\boxed{.}\boxed{5}\boxed{2}$

Use the following information to answer the next question.

Air pollution can be a serious problem in underground parking garages. The quantity of a particular pollutant in the air can be measured by passing a beam of light through the garage and measuring how much of it is absorbed. The light must have a wavelength that is strongly absorbed by the target pollutant.

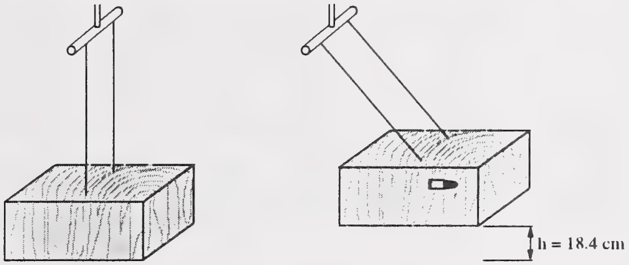
Numerical Response

2. A laser must be designed to supply a wavelength of 164 nm to detect a particular target pollutant. The search for a laser material begins with a list of hydrogen-like atoms/ions. The hydrogen-like atom whose 3-2 transition would emit light at 164 nm would have an E_1 value, expressed in scientific notation, of $-a.b \times 10^{-cd}$ J.

(Round and record your answer as $\boxed{a}\boxed{b}\boxed{c}\boxed{d}$.)

Answer: $\boxed{8}\boxed{7}\boxed{1}\boxed{8}$

Use the following information to answer the next question.



A ballistic pendulum is a device used to measure the speeds of fast moving objects like bullets. It consists of a wooden block with a mass of 1.00 kg.

A bullet with a mass of 5.00 g is fired from a gun with a barrel that is 74.2 cm long. The gun's mass is 2.45 kg. When the bullet strikes the block, it causes the block to rise to a height of 18.4 cm.

Numerical Response

3. The speed of the bullet just before it strikes the ballistic pendulum, expressed in scientific notation, is $a.bc \times 10^{d}$ m/s.

(Round and record your answer as $\boxed{a}\boxed{b}\boxed{c}\boxed{d}$.)

Answer: $\boxed{3}\boxed{8}\boxed{2}\boxed{2}$

Numerical Response

4. Place the following types of EMR in order of increasing energy:

1 blue light
2 gamma radiation
3 radio waves
4 ultraviolet radiation

(Record your answer on the answer sheet ☐☐☐☐.)

Answer: $\boxed{3}\boxed{1}\boxed{4}\boxed{2}$

Assessment of STS Connections

Students' understanding of the concepts of science are measured by every question on the examinations. In addition, some questions measure the students' understanding and use of skills associated with scientific inquiry. Some questions have been designed to measure the students' understanding of the connections between science and technology and among science, technology, and society. As a result, many questions measure how well students can apply the skills and knowledge they have acquired in science to everyday life.

Assessment of Communication Skills

Communication skills are assessed most directly in the teacher-scored questions. For the open-response questions, the descriptions used in the holistic scoring guides may include criteria for assessing communication skills along with criteria for the other components. Examples of scoring criteria can be found on pages 24 to 26.

The term *communication skills* includes those processes by which information is exchanged through appropriate conventions. These conventions include:

- words, sentences, paragraphs
- graphs, diagrams
- mathematical formulas, mathematical and chemical equations
- significant digits, units of measurement, unit conversion

Conventions that are considered appropriate for a particular response are subject- and question-specific.

One-Marker Scoring System

Each Physics 30 Diploma Examination has two written-response questions, one of which is a closed-response question. Each student's answer to this question is scored by one teacher using an analytic scoring guide. Each guide lists the criteria required for each mark, along with a sample response that meets all the criteria for a score of 10. For an example of this type of question and sample answers, see pages 19 to 22. Another example of this type of question can be found on the 1996 January Diploma Examination, written-response question 1.

Two-Marker Scoring System

The other written-response question is an open-response question. Students' answers to the open-response question are scored by teachers using holistic scoring guides. The guides describe the characteristics of students' answers that correspond to one of five values—0, 1, 2, 3, or 4 for the physics content used to solve the problem, and one of four values—0, 1, 2, or 3 for the effective communication of the response. Each student's answer is scored independently by two teachers. The two content scores are added together for a combined total sub-score out of 8, while the two communication scores are averaged for a sub-score out of 3. The two sub-scores are added together for a total out of 11.

A summary of the calculations follows:

Content: Reader 1 Score (X out of 4) + Reader 2 Score (Y out of 4) = Sub-score (X + Y out of 8)

Communication: Reader 1 Score (X out of 3) + Reader 2 Score (Y out of 3) divided by 2 = Sub-score ($\frac{X + Y}{2}$ out of 3)

Final score = Content (out of 8) + Communication (out of 3)

If the scores for content and/or communication obtained by the two independent readings vary by more than 2, the scores are classified as *discrepant*. Student responses that have *discrepant* scores are read by a third reader. The third reader must assign a score that is equal to one of the scores of the first two readers or between these scores.

A summary of the calculation for a discrepant paper follows:

Third Reader:

Content:	Reader 1	Score 1
	Reader 2	Score 3

Reader 3 must assign a 1, 2, or 3. This score will be doubled for a total out of 8.

Communication:	Reader 1	Score 1
	Reader 2	Score 3

Reader 3 must assign a 1, 2, or 3. This score will be added to the content score for a total out of 11.

For an example of this type of question, sample answers, and holistic scoring guides, see pages 23 to 31. Another example of this type of question can be found on the 1996 June Diploma Examination, written-response question 1.

Changes for 1997–98

NEW

For the Physics 30 diploma examinations in the 1997–98 school year, each of the written-response questions will be equally weighted at 15% of the total exam. The total for the written-response component will remain at 30% of the total exam.

The closed-response question will continue to be marked by one marker and the open-response question by two markers. The marking scheme for the closed-response question will change from a 10-point analytic scale to a analytic/holistic scoring guide. This guide will still be question specific but there will also be some general expectations. In order to be considered complete and correct, a student's response will need to clearly identify, in equations and words, the physics principles being used. The rubrics for scoring will include problem-solving skills, the application of physics knowledge, and mathematical competency. These scoring guides will be used in the 1996–97 school year on all written-response field tests.

The scoring system for the open-response question will continue to be based on a content scale and a communication scale, however, some adjustments may be made to the method by which the final mark is calculated.

Field Test Results

NEW

Field test results for the 1995–96 school year indicate that students and teachers are becoming more comfortable with the open-response questions. More students are attempting the questions, and their ability to clearly communicate their ideas has improved considerably.

Markers expressed concern regarding the lack of consistency in the methods used by students in plotting scientific data and in applying a suitable averaging technique to analyze the data. The following pages contain some comments about graphing and averaging procedures.

Comments About Graphing and Suitable Averaging Procedures

NEW

Students should be proficient at constructing graphs for scientific data. Some general guidelines for graphing scientific data follow.

1. The manipulated variable should be plotted on the horizontal axis, and the responding variable should be plotted on the vertical axis.

2. The scale for each axis should be set so that it spreads out the measured data as much as possible. Scales should be easy to read and evenly divided. All axes must be labelled with the variable used and complete units, including any power of 10.

3. The graph should have a clear title. This is usually stated as "Responding vs Manipulated" variable with a further descriptor to help identify the data.

4. Each data point should be plotted. A small circle may be drawn around each plotted point to indicate that it is a data point. Best fit lines or curves may not include all points due to experimental error. Best fit lines or curves do not necessarily include the origin.

Finding Slope

When asked to use an averaging technique to analyze a graph, students should be using slope or another suitable averaging method.

Generally, students understand that slope is defined as the rise/run. Some general guidelines for finding slope follow.

1. Always use on-line points that can be read easily.
2. The triangle should always be large, so as to minimize calculation errors.
3. Data points should not be used in a slope calculation.
4. The origin should not be used as a suitable point.
5. Units and powers of ten should be included in the calculation.
6. Significant digits for the slope are determined by the precision of the observations recorded in the data table.

Averaging Procedures

Students should be made aware that finding slope is the most suitable averaging procedure we have. Therefore, when they are asked to use an averaging procedure to analyze data, slope should be their first choice. If they do not use slope, then they should use the average of the desired values, or the weighted mean should be used (not the average of the manipulated and responding variables). Care must be taken when using these averaging methods because the origin or another non-permissible value may be given as data. An example illustrating both a slope calculation and another suitable averaging procedure, and their use, follows.

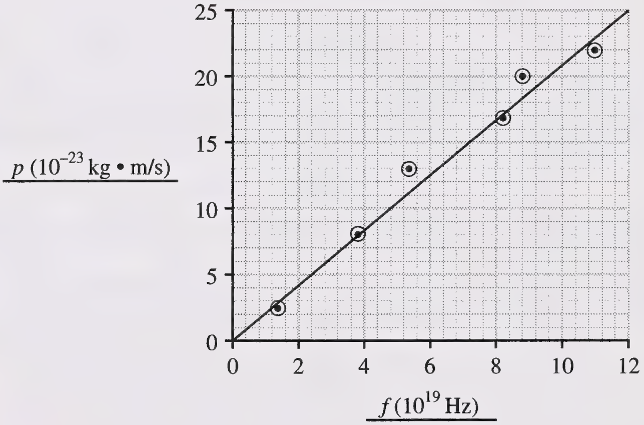
Example

Independent measurements were made of the momentum p and of the frequency f of X-rays. The results are summarized in the table:

p (10^{-23} kg•m/s)	f (10^{19} Hz)
2.5	1.3
8.0	3.9
13.0	5.4
17.0	8.1
20.0	8.8
22.0	11.2

a. From the data in the table, plot a graph of momentum as a function of frequency, placing frequency on the horizontal axis.

Momentum as a Function of Frequency



b. Use the slope of the graph or some other suitable averaging procedure to determine the **best** estimate of Planck's constant h.

Slope Method

slope $= \Delta p/\Delta f$

$$= \frac{(19 - 6.0)(10^{-23}\ \text{kg•m/s})}{(8.8 - 2.8)(10^{19}\ \text{Hz})}$$

slope $= 2.2 \times 10^{-42}$ kg•m

Here, the slope is not Planck's constant but must be used to find h.

$$p = hf/c$$

$$p/f = h/c$$

$$h = c(\text{slope})$$

$$= (3.00 \times 10^{8}\ \text{m/s})(2.16 \times 10^{-42}\ \text{kg•m})$$

$$h = 6.5 \times 10^{-34}\ \text{J•s}$$

For the slope calculation, all six guidelines were followed.

Averaging Method: using data points

$$h = pc/f$$

$$h_1 = (2.5 \times 10^{-23}\ \text{kg•m/s})(3.00 \times 10^{8}\ \text{m/s})/(1.3 \times 10^{19}\ \text{Hz})$$

$$= 5.8 \times 10^{-34}\ \text{J•s}$$

$$h_2 = 6.2 \times 10^{-34}\ \text{J•s}$$

$$h_3 = 7.2 \times 10^{-34}\ \text{J•s}$$

$$h_4 = 6.3 \times 10^{-34}\ \text{J•s}$$

$$h_5 = 6.8 \times 10^{-34}\ \text{J•s}$$

$$h_6 = 5.8 \times 10^{-34}\ \text{J•s}$$

$$h_{(\text{ave})} = \frac{h_1 + h_2 + h_3 + h_4 + h_5 + h_6}{6}$$

$$= 6.4 \times 10^{-34}\ \text{J•s}$$

In finding the average value for Planck's constant, all six values were calculated. These values were then averaged. This method may yield different results because of the inclusion of points that have large experimental errors. Note that the averaging equation was explicitly stated. However, it is acceptable to state the averaging equation implicitly.

In this particular problem, the following method yields a reasonable value for Planck's constant but is generally considered unacceptable.

$$p_{(\text{ave})} = \frac{\Sigma p}{6} \qquad = 13.8 \times 10^{-23}\ \text{kg•m/s}$$

$$f_{(\text{ave})} = \frac{\Sigma f}{6} \qquad = 6.45 \times 10^{19}\ \text{Hz}$$

$$h_{(\text{ave})} = \frac{p_{(\text{ave})} \cdot c}{f_{(\text{ave})}} \qquad = 6.4 \times 10^{-34}\ \text{J•s}$$

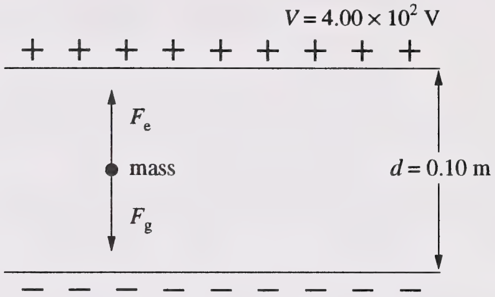
This method gives the correct answer **only** because the graph goes through the origin; as a general practice, the origin should **not** be used. Often, when experimental errors are present, graphs that are meant to go through the origin do not go through it. Thus, the use of this particular procedure involves making an unwarranted assumption.

Scoring of Sample Answers

Written-Response Question 2, June 1996

Use the following information to answer the next question.

A Millikan Experiment



A charged particle that has a mass of 2.8×10^{-16} kg accelerates upward at $3.6\ \text{m/s}^2$ in the electric field between two horizontal plates that have a separation of 0.10 m. The potential difference across the plates is 4.0×10^2 V. The experiment is performed on Earth's surface at sea level.

2. **a.** Calculate the magnitude and direction of the electric force exerted upon the particle.

$$F_e = mg + ma \qquad \text{OR} \qquad \Sigma F = F_{net} = ma$$

$$F_e = (2.8 \times 10^{-16}\ \text{kg})(9.81\ \text{m/s}^2) + (2.8 \times 10^{-16}\ \text{kg})(3.6\text{m/s}^2)$$

$$F_e = 2.7468 \times 10^{-15}\ \text{N} + 1.008 \times 10^{-15}\ \text{N}$$

$$F_e = 3.7548 \times 10^{-15} \quad \therefore \ \text{direction is up}$$

$$F_e = 3.8 \times 10^{-15}\ \text{N}$$

There are **four** checks for this part:

1. using $F_e = mg + ma$ or equivalent
2. substitution into a valid formula
3. answer $F_e = 3.8 \times 10^{-15}$ N
4. answer direction upward

b. Determine the charge on the particle. (If you were unable to answer part **a**, use the hypothetical value $F_e = 2.6 \times 10^{-15}$ N.)

$$|\vec{E}| = \frac{V}{d}$$

$$|\vec{E}| = \frac{F_e}{q}$$

$$F_e = \frac{V}{d} q$$

$$3.7548 \times 10^{-15}\ \text{N} = \frac{4.00 \times 10^2\ \text{V} \times q}{0.10\ \text{m}} \quad : \ 1\ \text{V} = 1\ \text{J/C}$$

$$\frac{(3.7548 \times 10^{-15}\ \text{N})(0.10\ \text{m})}{4.00 \times 10^2\ \text{J/C}} = q$$

$q = 9.387 \times 10^{-19}$ C (accept to 9.5×10^{-19} C)

If $F = 2.6 \times 10^{-15}$ N then $q = 6.5 \times 10^{-19}$ C

There are **five** checks for this part:

5. stating $|\vec{E}| = \frac{V}{d}$ or equivalent or $F_T = mg + ma$
6. stating $|\vec{E}| = \frac{F_e}{q}$ or equivalent
7. equating electric fields or equating forces or calculating and substituting $|\vec{E}|$
8. substitution into a valid formula
9. answer $q = 9.4 \times 10^{-19}$ C or consistent with calculation

c. Determine the time required for the particle to move from the lower to the upper plate when the particle begins at rest.

$$d = v_i t + \frac{1}{2} a t^2 \ : \ v_i = 0$$

$$t = \sqrt{2\, d / a}$$

$$t = \sqrt{2\,(0.10\ \text{m}) / (3.6\ \text{m/s}^2)}$$

$$t = \sqrt{0.0556\ \text{s}^2}$$

$$t = 0.2357\ \text{s}$$

There are **four** checks for this part:

10. stating $d = v_i t + \frac{1}{2} a t^2$ or equivalent OR $\Delta E = qV = mgh + m v_f{}^2/2$
11. stating $t = \sqrt{2\, d / a}$ or $v_i = 0$ or equivalent OR calculating v_f correctly
12. substitution into valid formula OR using $\Delta t = (v_f - v_i)/a$ or equivalent
13. answer $t = 0.24$ s or consistent with calculation

d. Assume that the voltage applied to the plates can be varied. Calculate the minimum voltage needed to move the particle from the lower plate to the upper plate. (If you were unable to answer part **b**, use the hypothetical value 9.6×10^{-19} C as the charge on the particles.)

$$F_e = mg$$

$$\frac{qV}{d} = mg$$

$$V = \frac{mgd}{q}$$

$$V = \frac{(2.8 \times 10^{-16}\ \text{kg})(9.81\ \text{m/s}^2)(0.10\ \text{m})}{9.37 \times 10^{-19}\ \text{C}}$$

$$V = 2.926 \times 10^2\ \text{V}$$

A student must state that the voltage is greater than 2.9×10^2 V

$$V > 2.9 \times 10^2\ \text{V}$$

If the hypothetical $q = 6.5 \times 10^{-19}$ C then $V > 4.3 \times 10^2$ V

There are **four** checks for this part:

14. stating $F_e = mg$ or equivalent
15. stating $F_e = \frac{qV}{d}$ or equivalent
16. substitution into a valid formula
17. answer Voltage is greater than 2.9×10^2 V or consistent with calculation

e. Assume now that the particle is at rest between the plates. If the charges on the plates were inverted (negative plate becomes positive, and positive plate becomes negative), what would be the magnitude and direction of the net force on the particle?

Method 1:

$$\Sigma F = F_{\text{net}} \ : \ F_e = F_g$$

$$-F_g - F_g = F_{\text{net}}$$

$$F_{\text{driving}} = 2F_g \text{ downwards} = F_{\text{net}}$$

There are **three** checks for this part:

18. stating $F_e = F_g$
19. answer $F_{\text{net}} = 2F_g$
20. answer direction = downward

Method 2:

$$F_e = \frac{qV}{d}$$

$$= \frac{(9.37 \times 10^{-19}\ \text{C})(2.93 \times 10^{2}\ \text{V})}{(0.10\ \text{m})}$$

$$F_e = 2.75 \times 10^{-15}\ \text{N}$$
$$F_g = mg$$
$$= (2.8 \times 10^{-16}\ \text{kg})(9.81\ \text{m/s}^2)$$
$$F_g = 2.75 \times 10^{-15}\ \text{N}$$

$$F = F_e + F_g$$
$F = 5.5 \times 10^{-15}$ N; downwards :

or using $V = 400$ V, $F = 6.5 \times 10^{-15}$ N; downwards

There are three checks for this part:

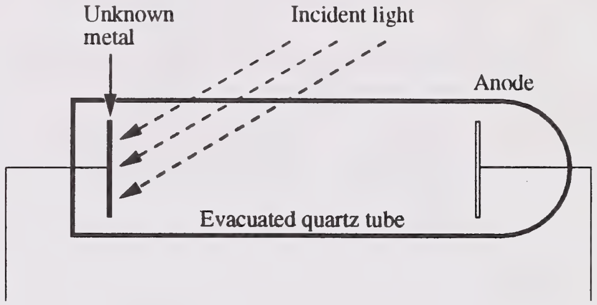
18. stating $F_{net} = F_g + F_e$ or equivalent
19. an answer $F_{NET} = 5.5 \times 10^{-15}$ N or $F_{NET} = 6.5 \times 10^{-15}$ N or consistent with calculation
20. downwards

Checks	Marks
19 or 20	10
17 or 18	9
15 or 16	8
14	7
12 or 13	6
10 or 11	5
8 or 9	4
6 or 7	3
4 or 5	2
2 or 3	1
0 or 1	0

Written-Response Question 2, January 1996

Use the following information to answer the next question.

The labels have fallen off two evacuated tubes that have unknown metals at each cathode. One tube, with Metal X as its cathode, detects visible light leakage from cameras. The other tube, with Metal Y as its cathode, detects ultraviolet leakage from shielded equipment. A student needs to know which tube is which. One of the evacuated tubes is shown below.



Also available is a variable-frequency electromagnetic wave source, a variable voltage source, a voltmeter, and any reference tables needed.

2. Design an experiment using the photoelectric effect to distinguish between Metal X and Metal Y. Your experimental design must contain:

- Statement of the purpose of the experiment
- List of the equipment needed
- A complete labelled diagram (above) of all the equipment necessary
- Procedure
- Measurements to be made and recorded, and any tables necessary
- Description of the analysis to be done
- An explanation using either the calculation or the derived algebraic equation showing how it will be used to distinguish between Metal X and Metal Y.

Note: A maximum of 8 marks will be awarded for the physics used in your design. A maximum of 3 marks will be awarded for the effective communication of your response.

Written-Response Question 2—Holistic Scoring Guide
Reporting Category: Physics COMMUNICATION

When marking COMMUNICATION, the marker should consider how effectively the response *describes the experimental design used to distinguish between Metal X and Metal Y.*

Score	Criteria
3 **Excellent** **(80%)**	The response: • is complete, well organized, and clear and relevant to the topic • describes a detailed experimental design in a logical manner demonstrating consistency of thought • uses physics vocabulary appropriately, and a precise, explicit relationship exists between the experiment and the diagram(s) • explicitly states formulas, equations, or relationships used to distinguish between Metal X and Metal Y • may have a minor error or omission but this does not hinder the communication of the design
2 **Satisfactory**	The response: • is somewhat complete and organized, however, it lacks clarity • describes an experimental design but details are general and/or sometimes lacking, leaving it somewhat open to interpretation • uses physics vocabulary, however, this is sometimes misused, and an implicit relationship exists between the experiment and the diagram(s) • includes formulas, equations, or relationships that may be inferred when used to distinguish between Metal X and Metal Y • likely has errors or omissions that may hinder the communication of the design
1 **Poor**	The response: • is incomplete, unorganized, and somewhat unclear • describes an experimental design but provides little or no detail • uses physics vocabulary, however, this is often misused, and there is a weak relationship between the experiment and the diagram(s) • includes formulas, equations, or relationships that may be inferred by analyzing the explanation • has errors and/or omissions that hinder the communication of the design
0	The response: • is not complete, organized, or clear • does not describe a design • uses little or no physics vocabulary and there is no relationship between the explanation (if present) and the diagram (if present) • may state a formula, equation, or relationship but it does not contribute to the design • is confusing and/or frustrating to the reader • has very little written
NR	No response is given.

Written-Response Question 2—Holistic Scoring Guide
Reporting Category: Physics CONTENT

When marking CONTENT, the marker should consider how effectively the response uses physics concepts, knowledge, and skills in the *design of the experiment using the photoelectric effect to distinguish between Metal X and Metal Y.*	
Score	**Criteria**
4 **Standard of Excellence** **(80%)**	The response: • shows the design of an experiment that reflects a *thorough understanding* of the photoelectric effect by *correctly distinguishing* between Metal X and Metal Y. • contains an *accurate statement* of the purpose, a *complete list* of the equipment needed, and a *procedure that supports* the experimental design • *identifies measurements* to be made and *refers to any tables* necessary • *accurately describes* the analysis to be done in order to distinguish between Metal X and Metal Y • *may contain minor errors* in the equations and/or concepts, however, these *do not hinder the understanding* of the physics content • has *no major inconsistencies*
3	The response: • shows the design of an experiment that reflects a *good understanding* of the photoelectric effect but that may produce *difficulty distinguishing* between Metal X and Metal Y • contains a *correct statement* of the purpose, a list of *most of the equipment* needed, and a *procedure that provides support* for the experimental design • identifies *most measurements* to be made and *likely refers* to any tables necessary • *describes the analysis* to be done in order to distinguish between Metal X and Metal Y • *may contain minor errors* in equations and/or concepts *that hinder* the understanding of the physics content • *may have several minor inconsistencies* or perhaps *one major inconsistency* (omits accurate description of the analysis) although there is little doubt that there is good understanding
2 **Acceptable Standard** **(50%)**	The response: • shows the design of an experiment that reflects a *partial understanding* of the photoelectric effect and that *most likely does not distinguish* between Metal X and Metal Y • *contains a statement* of the purpose, a list of *some of the equipment* needed, and a *procedure that provides support* for the experimental design • *identifies few measurements* to be made and *likely fails to refer* to any tables • describes *some of the analysis* to be done in order to distinguish between Metal X and Metal Y • *contains minor errors* in equations and/or concepts that *hinder the understanding* of the physics content • has *inconsistencies or a major omission* that indicates a partial understanding

1	The response: • shows the design of an experiment that reflects a *poor understanding* of the photoelectric effect and *does not distinguish* between Metal X and Metal Y; may recognize some aspects of the photoelectric effect • *may contain a statement* of the purpose, a list of *equipment*, and a *procedure* that *may or may not support* the experimental design • *may identify measurements* and/or reference tables, however, their use is likely *inappropriate and/or incorrect* • *describes little or no analysis* to be done in order to distinguish between Metal X and Metal Y • contains major errors in equations and/or concepts, indicating poor understanding of the physics content • has *minor and major inconsistencies and/or omissions*
0	The response: • shows the design, if present, of an experiment that reflects *little or no understanding* of the photoelectric effect • provides *no statement of purpose, no list of equipment*, and *no procedure* • provides *no measurements* or *analysis* • has *major omissions*
NR	No response provided

Student Sample One

Communication Score—2

Rationale: The response is well organized and includes all of the required elements; however, it is unclear from the procedure given exactly what measurements are to be made, and once made, whether those measurements will support the analysis, i.e., the analysis requires stopping voltage to be measured but this is not specified in the procedure.

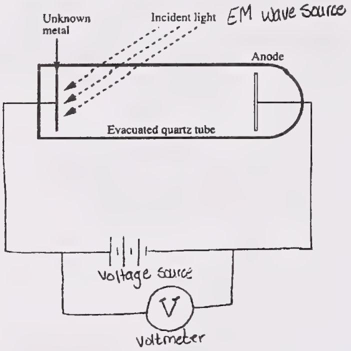
Content Score—4

Rationale: The response addresses all of the required elements. The explanation reflects a thorough understanding of the photoelectric effect. Although metal x and metal y are not identified, the process by which they could be is outlined. Use of all formulas is correct.

Written Response – 11 marks

Use the following information to answer written-response question 2.

The labels have fallen off two evacuated tubes that have unknown metals at each cathode. One tube, with Metal X as its cathode, detects visible light leakage from cameras. The other tube, with Metal Y as its cathode, detects ultraviolet leakage from shielded equipment. A student needs to know which tube is which. One of the evacuated tubes are shown below.



Also available is a variable-frequency electromagnetic wave source, a variable voltage source, a voltmeter, and any reference tables needed.

The purpose of this experiment is to use a variable voltage source and a variable frequency electromagnetic wave source in order to discover the threshold frequencies of the metals. Since each metal has a different threshold frequency we will then be able to identify the metals.

MATERIALS

1. Variable frequency electromagnetic wave source.
2. variable voltage source
3. Volt meter
4. unknown metals (x & Y)
5. reference tables giving threshold frequencies.

PROCEDURE

1. Set frequency of EM wave source
2. Set and measure voltage
3. Raise voltage until electron movement stops
4. Repeat for other metal
5. It is helpful to repeat the procedure for better accuracy.
6. Record results.

RESULTS Metal x:

Trial	Stopping V(V)	E_{kmax}(J)	Frequency (Hz)	f_0 (Hz)
1 ⋮				
AVE				

Metal Y:

Trial	Stopping V(V)	E_{kmax}(J)	Freq. (Hz)	f_0 (Hz)
1 ⋮				
Ave.				

ANALYSIS

formulas:

$$E_{kmax} = q \cdot V_{stop}$$
$$= h(f - f_0)$$
$$\therefore q V_{stop} = h(f - f_0)$$
$$f_0 = \frac{q V_{stop}}{h} + f$$

$q = 1.60 \times 10^{-19}\ C$

$h = 6.63 \times 10^{-34}\ Js$

Use these formulas and constants in order to find the threshold frequency of each metal.

Content 4 × 2 = 8

Communication 2

$\frac{10}{11}$

Student Sample Two

Communication Score—3

Rationale: The response is well organized, relevant and clear. The response specifies a detailed procedure which demonstrates a logical, consistent approach. There is a precise relationship between the experiment and the diagram, and the formulae necessary to distinguish between metal x and metal y are explicitly stated.

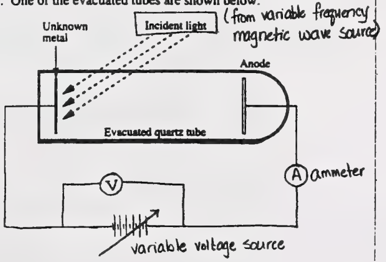
Content Score—3

Rationale: The response addresses all of the required elements and reflects a good understanding of the photoelectric effect. Although the concept of threshold frequency is clearly outlined in the explanation, the procedure given will not produce the measurements needed. As evidenced by the discussion and diagram, the student clearly does not recognize that stopping potential of the photoelectrons is needed to compute the kinetic energy of those photoelectrons, and consequently, the threshold frequency of metals x and y. Therefore, the procedure will be unlikely to distinguish between metal x and metal y.

Written Response – 11 marks

Use the following information to answer written-response question 2.

The labels have fallen off two evacuated tubes that have unknown metals at each cathode. One tube, with Metal X as its cathode, detects visible light leakage from cameras. The other tube, with Metal Y as its cathode, detects ultraviolet leakage from shielded equipment. A student needs to know which tube is which. One of the evacuated tubes are shown below.



f_0 for u.v. light higher
f_0 for visible light lower.

Also available is a variable-frequency electromagnetic wave source, a variable voltage source, a voltmeter, and any reference tables needed.

Analysis: Because we know that ultraviolet light has a higher frequency than visible light and that both EMR are next to each other on the light spectrum, we can conclude that the threshold frequency of the metal to detect Ultra Violet light will be higher than the threshold frequency of the metal to detect visible light

Because the electrons in the cathode start out with an initial E_k of 0V (not moving) $\Delta E = E_{k2}$ $(\Delta E = E_{k2} - E_{k1})$

Find E_K usind $V = \frac{\Delta E}{q}$, $q = 1.60 \times 10^{-19}$ C (electron)

$\Delta E = E_K$ V = use average max voltage separately for metal x & Y.

Once E_K for both metal x and metal y is calculated, solve for the threshold frequency of each metal (f_0)

$E_K = hf - W$ where $W = hf_0$ $h = 6.63 \times 10^{-34}$ Js
f = average min. freq. from chart.

f_0 for metal x = ______
f_0 for metal y = ______

The metal with the higher threshold frequency is used to detect ultra violet light and the metal with the lower threshold frequency is used to detect visible light.

EXPERIMENT (THRESHOLD FREQUENCY)

Purpose: To correctly identify and label the cathode ray tubes containing metal x and metal y according to the EMR it detects: either visible or ultraviolet.

Materials: cathode ray tubes containg metal x and metal y.
variable frequency electromagnetic wave source
variable voltage source
volt meter
dark room
ammeter (if available)

Procedure:
1. Set up the apparatus shown in the diagram in a darkroom.
2. Turn on the power supply so that a cathode ray can be seen between the cathode and the anode
3. Slowly reduce the voltage until the current is 0A. but there is still an electric potential difference on the cathode. Record the voltage at which this occurs (if an ammeter isn't available, wait until no cathode ray can be seen.)
4. Using the variable-frequency electromagnetic wave source, shine incident light on Metal x with the lowest possible frequency.
5. Slowly increase ~~the~~ frequency of the incident light until a current can be detected by the ammeter. Record the frequency of the incident light at which this occurs.
6. Repeat steps #2-5 with metal x 5-10 times so that there is minimal experimental error.
7. Now follow steps 2-6 with metal y.

Observations: In the table [on the next page] record the max. voltage at which no current was detected (step 3) and the min. frequency at which a current was detected (step 5). The average for these values can be found by adding the values and dividing by the # of values.

	Metal X		Metal Y	
Trial #	Max V	Min f	Max V	Min f
1				
2				
⋮				
10				

Content	3 × 2 = 6
Communication	3
	9/11

Student Sample Three

Communication Score—2

Rationale: The response is well organized; however, it fails to address the requirement of using either a calculation or a derived algebraic expression. Incomplete answers cannot be awarded full communication marks.

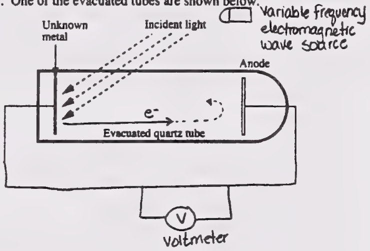
Content Score—2

Rationale: The response identifies a procedure that reflects a partial understanding of the photoelectric effect. It does not directly address the concept of threshold frequency, which must be inferred from the procedure. The setup, as shown in the diagram, is unlikely to provide the measurements needed to support the analysis.

Written Response – 11 marks

Use the following information to answer written-response question 2.

The labels have fallen off two evacuated tubes that have unknown metals at each cathode. One tube, with Metal X as its cathode, detects visible light leakage from cameras. The other tube, with Metal Y as its cathode, detects ultraviolet leakage from shielded equipment. A student needs to know which tube is which. One of the evacuated tubes are shown below.



Also available is a variable-frequency electromagnetic wave source, a variable voltage source, a voltmeter, and any reference tables needed.

Purpose: Which of the two metals is metal x and which is metal y ?

Equipment: evacuated tube containing metal x
evacuated tube containing metal y
variable-frequency electromagnetic wave source
~~variable voltage source~~
volt meter

Procedure:
1. connect apparatus as shown in the diagram to the left.
2. turn on the variable-frequency electromagnetic wave source to the frequency of visible light. Turn up the frequency until there is a reading on the voltmeter.
3. record the frequency
4. if there is no reading in the visible light range, increase the frequency of the variable frequency electromagnetic wave source slowly until there is a reading on the voltmeter. Measure and record the frequency.

DATA:

	ν (Hz)	$V_{reading}$ (Yes/No)
Tube 1	visible light	N.
Tube 2	visible light	Y
Tube 1	UV light	Y
Tube 2	UV light	Y

Analysis: Tube 2 (not Tube 1) responded to visible light.
Tube 1 (and Tube 2) responded to U.V. light.

Conclusion: Tube 2 contains metal x. Tube 1 contains metal y. We know this because Tube 2 only responded to visible light.

Content 2 × 2 = 4
Communication 2

$\frac{6}{11}$

Student Sample Four

Communication Score—1

Rationale: The response is incomplete and somewhat unclear. There is an attempt to describe an experimental design but little or no detail is provided. There is a general misuse of physics vocabulary and a very weak relationship between the experiment and the diagram.

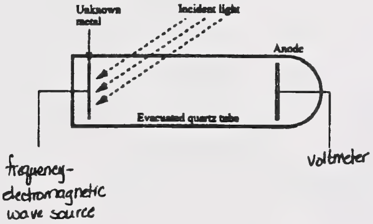
Content Score—1

Rationale: The response contains a statement of purpose, list of equipment, and a procedure. However, although the procedure uses the term "threshold frequency," it indicates a very poor understanding of the photoelectric effect. There are no measurements indicated. Finally, the response provides no analysis in order to distinguish between the metals.

Written Response – 11 marks

Use the following information to answer written-response question 2.

The labels have fallen off two evacuated tubes that have unknown metals at each cathode. One tube, with Metal X as its cathode, detects visible light leakage from cameras. The other tube, with Metal Y as its cathode, detects ultraviolet leakage from shielded equipment. A student needs to know which tube is which. One of the evacuated tubes are shown below.



Also available is a variable-frequency electromagnetic wave source, a variable voltage source, a voltmeter, and any reference tables needed.

First of all, the Photoelectric Effect occurs when electrons are emitted immediataly after coming into contact with a metal surface. But in order for the electrons to even be emitted, a threshold frequency must be met.

Purpose: To determine metal X and metal Y in two evacuated tubes, using the photoelectric effect.

Materials:
- Voltmeter
- variable voltage source
- frequency - electromagnetic wave source
- Anode
- Evacuated Quartz tube
- 2 unknown metals
- incident light

Procedure:
The threshold frequency of each metal needs to be met, so shine the incident light onto the unknown metals. This will need various tries. Keep increasing the light source while measuring the frequency with the variable frequency - electromagnetic wave source. Eventually the threshold frequency will be met on both metals and from there, we can calculate and determine which metal is which.

Content 1 × 2 = 2
Communication 1

3/11

Student Sample Five

Communication Score—1

Rationale: The response is incomplete and somewhat unclear. There is an attempt to describe an experimental design but little or no detail is provided. There is a general misuse of physics vocabulary and a weak relationship between the experiment and the diagram.

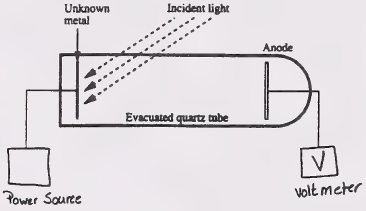
Content Score—0

Rationale: The response contains a statement of purpose, list of equipment, and a procedure; however, the procedure indicates little or no understanding of the photoelectric effect. The response incorrectly identifies measurements to be made and provides no analysis.

Written Response – 11 marks

Use the following information to answer written-response question 2.

The labels have fallen off two evacuated tubes that have unknown metals at each cathode. One tube, with Metal X as its cathode, detects visible light leakage from cameras. The other tube, with Metal Y as its cathode, detects ultraviolet leakage from shielded equipment. A student needs to know which tube is which. One of the evacuated tubes are shown below.



Also available is a variable-frequency electromagnetic wave source, a variable voltage source, a voltmeter, and any reference tables needed.

Purpose: to determine what Metal X and Metal Y are and the difference between the 2 tubes.

Materials:
- cathode tubes
- voltmeter
- power source
- electromagnetic wave source

Procedure:
- shine different coloured lights upon the tubes until there is a voltmeter reading fluctuation

Measurements:
- volt readings
- power input readings

Analyze what has happened when the different coloured light is shone upon the tube.
The different wavelengths will correspond to different wavelengths of the metal distinguishing them.

Content	0 × 2 = 0
Communication	1
	$\frac{1}{11}$

Appendix A

Appendix B

Guidelines for Significant Digits, Manipulation of Data, and Rounding in the Sciences Diploma Examinations

Significant Digits (measured values)

1. For all non-logarithmic values, regardless of decimal position, any of the digits 1 to 9 is a significant digit; 0 may be significant. For example:

   123 0.123 0.00230 2.30×10^3
   all have 3 significant digits

2. Leading zeros are not significant. For example:

   0.12 and 0.012 each have two significant digits

3. Trailing zeros to the right of the decimal are significant. For example:

   0.123 00 and 20.000 each have five significant digits

4. Zeros to the right of a whole number are considered to be ambiguous. **The Student Evaluation Branch considers all trailing zeros to be significant**. For example:

   200 has three significant digits

5. For logarithmic values, such as pH, any digit to the left of the decimal is **not** significant. For example:

   a pH of 1.23 has two significant digits
   a pH of 7 has no significant digits

Manipulation of Data

1. When adding or subtracting measured quantities, the calculated answer should be rounded to the same degree of precision as that of the least precise number used in the computation **if this is the only operation**. For example:

   12.3 (least precise)
   0.12
   $\underline{12.34}$
   24.76

   The answer should be rounded to 24.8.

2. When multiplying or dividing measured quantities, the calculated answer should be rounded to the same number of significant digits as are contained in the quantity with the fewest number of significant digits **if this is the only operation**. For example:

   (1.23)(54.321) = 66.81483

   The answer should be rounded to 66.8.

3. **When a series of calculations is performed, each interim value should not be rounded before carrying out the next calculation.** The final answer should then be rounded to the same number of significant digits as are contained in the quantity in the original data with the fewest number of significant digits. For example:

   In determining the value of (1.23)(4.321)/(3.45 – 3.21), three calculations are required:

   a. 3.45 – 3.21 = 0.24

   b. (1.23)(4.321) = 5.31483

   c. 5.31483/0.24 = 22.145125

      [Not 5.31/0.24 = 22.125]

   The value should be rounded to 22.1.

   Note: In the example given, steps *a* and *b* yield interim values. These values should not be used in determining the number of significant digits.

NEW

4. When calculations involve exact numbers (counted and defined values) the calculated answer should be rounded based upon the measured value(s). For example:

   12 eggs × 52.3 g/egg = 628 g

Rounding

1. When the first digit to be dropped is less than or equal to 4, the last digit retained should not be changed. For example:

   1.2345 rounded to three digits is 1.23

2. When the first digit to be dropped is greater than or equal to 5, the last digit retained should be increased by one. For example:

   12.25 rounded to three digits is 12.3

Appendix C

Directing Words

Discuss

The word “discuss” will not be used as a directing word on math and science diploma examinations because it is not used consistently to mean a single activity

The following words are specific in meaning.

Compare

Examine the character or qualities of two things by providing characteristics of both that point out their mutual *similarities* and *differences*

Conclude

State a logical end based on reasoning and/or evidence

Contrast/Distinguish

Point out the *differences* between two things that have similar or comparable natures

Criticize

Point out the *merits* and *demerits* of an item or issue

Define

Provide the essential qualities or meaning of a word or concept; make distinct and clear by marking out the limits

Describe

Give a written account or represent the characteristics of something by a figure, model, or picture

Design/Plan

Construct a plan, i.e., a detailed sequence of actions, for a specific purpose

Enumerate

Specify one by one or list in concise form and according to some order

Evaluate

Give the significance or worth of something by identifying the good and bad points or the advantages and disadvantages

Explain

Make clear what is not immediately obvious or entirely known; give the cause of or reason for; make known in detail

How

Show in what manner or way, with what meaning

Hypothesize

Form a tentative proposition intended as a possible explanation for an observed phenomenon; i.e., a possible cause for a specific effect. The proposition should be testable logically and/or empirically

Identify

Recognize and select as having the characteristics of something

Illustrate

Make clear by giving an example. The form of the example must be specified in the question; i.e., word description, sketch, or diagram

Infer

Form a generalization from sample data; arrive at a conclusion by reasoning from evidence

Interpret

Tell the meaning of something, present information in a new form that adds meaning to the original data

Justify/Show How

Show reasons for or give facts that support a position

Outline

Give, in an organized fashion, the essential parts of something. The form of the outline must be specified in the question; i.e., lists, flow charts, concept maps

Predict

Tell in advance on the basis of empirical evidence and/or logic

Prove

Establish the truth, validity, or genuineness of something by giving factual evidence or logical reasons

Relate

Show logical or causal connection between things

Solve

Give a solution for a problem; i.e., explanation in words and/or numbers

Summarize

Give a brief account of the main points

Trace

Give a step-by-step description of the development

Why

Show the cause, reason, or purpose

Appendix D

Science Process Words

Hypothesis:	A single proposition intended as a possible explanation for an observed phenomenon; e.g., a possible cause for a specific effect
Conclusion:	A proposition that summarizes the extent to which a hypothesis and/or a theory has been supported or contradicted by the evidence
Experiment:	A set of manipulations and/or specific observations of nature that allow the testing of hypotheses and/or generalizations
Variables:	Conditions that can change in an experiment. Variables in experiments are categorized as: • *manipulated variables* (independent variables)—conditions that were deliberately changed by the experimenter • *controlled variables* (fixed or restrained variables)—conditions that could have changed but did not, because of the intervention of the experimenter • *responding variables* (dependent variables)—conditions that changed in response to the change in the manipulated variables
Technology:	The development of our understanding of science is directly related to the development of technology. The meaning of technology has many facets, but in general, technology refers to a way of doing something. This includes the development of tools and new techniques for solving problems. It also includes ideas and their organization for achieving practical purposes. In the context of an examination question, technology includes both these facets of meaning. That is, a technological explanation should include not only identification and descriptions of equipment (tools, products) but also explanations of procedures.

Periodic Table of the Elements

Key

Atomic number → 3 Li ← Symbol

Atomic molar mass → 6.94

Name → lithium

Based on $^{12}_{6}C$

( ) Indicates mass of the most stable isotope

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
IA	IIA	IIIB	IVB	VB	VIB	VIIB		VIIIB	VIIIB	IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA or O
1 H 1.01 hydrogen																	2 He 4.00 helium
3 Li 6.94 lithium	4 Be 9.01 beryllium											5 B 10.81 boron	6 C 12.01 carbon	7 N 14.01 nitrogen	8 O 16.00 oxygen	9 F 19.00 fluorine	10 Ne 20.17 neon
11 Na 22.99 sodium	12 Mg 24.31 magnesium											13 Al 26.98 aluminum	14 Si 28.09 silicon	15 P 30.97 phosphorus	16 S 32.06 sulphur	17 Cl 35.45 chlorine	18 Ar 39.95 argon
19 K 39.10 potassium	20 Ca 40.08 calcium	21 Sc 44.96 scandium	22 Ti 47.90 titanium	23 V 50.94 vanadium	24 Cr 52.00 chromium	25 Mn 54.94 manganese	26 Fe 55.85 iron	27 Co 58.93 cobalt	28 Ni 58.71 nickel	29 Cu 63.55 copper	30 Zn 65.38 zinc	31 Ga 69.72 gallium	32 Ge 72.59 germanium	33 As 74.92 arsenic	34 Se 78.96 selenium	35 Br 79.90 bromine	36 Kr 83.80 krypton
37 Rb 85.47 rubidium	38 Sr 87.62 strontium	39 Y 88.91 yttrium	40 Zr 91.22 zirconium	41 Nb 92.91 niobium	42 Mo 95.94 molybdenum	43 Tc (98.91) technetium	44 Ru 101.07 ruthenium	45 Rh 102.91 rhodium	46 Pd 106.40 palladium	47 Ag 107.87 silver	48 Cd 112.41 cadmium	49 In 114.82 indium	50 Sn 118.69 tin	51 Sb 121.75 antimony	52 Te 127.60 tellurium	53 I 126.90 iodine	54 Xe 131.30 xenon
55 Cs 132.91 cesium	56 Ba 137.33 barium	57-71	72 Hf 178.49 hafnium	73 Ta 180.95 tantalum	74 W 183.85 tungsten	75 Re 186.21 rhenium	76 Os 190.20 osmium	77 Ir 192.22 iridium	78 Pt 195.09 platinum	79 Au 196.97 gold	80 Hg 200.59 mercury	81 Tl 204.37 thallium	82 Pb 207.19 lead	83 Bi 208.98 bismuth	84 Po (208.98) polonium	85 At (209.98) astatine	86 Rn (222.02) radon
87 Fr (223.02) francium	88 Ra (226.03) radium	89-103	104 Unq (266.11) unnilquadium	105 Unp (262.11) unnilpentium	106 Unh (263.12) unnilhexium	107 Uns (262.12) unnilseptium	108 Uno (265) unniloctium	109 Une (266) unnilennium									
			57 La 138.91 lanthanum	58 Ce 140.12 cerium	59 Pr 140.91 praseodymium	60 Nd 144.24 neodymium	61 Pm (144.91) promethium	62 Sm 150.35 samarium	63 Eu 151.96 europium	64 Gd 157.25 gadolinium	65 Tb 158.93 terbium	66 Dy 162.50 dysprosium	67 Ho 164.93 holmium	68 Er 167.26 erbium	69 Tm 168.93 thulium	70 Yb 173.04 ytterbium	71 Lu 174.97 lutetium
			89 Ac (277.03) actinium	90 Th (232.04) thorium	91 Pa (231.04) protactinium	92 U 238.03 uranium	93 Np (237.05) neptunium	94 Pu (244.06) plutonium	95 Am (243.06) americium	96 Cm (247.07) curium	97 Bk (247.07) berkelium	98 Cf (242.06) californium	99 Es (252.08) einsteinium	100 Fm (257.10) fermium	101 Md (258.10) mendelevium	102 No (259.10) nobelium	103 Lr (260.11) lawrencium

PHYSICS DATA SHEETS

CONSTANTS

Gravity, Electricity, and Magnetism

Acceleration Due to Gravity or Gravitational Field Near Earth	a_g or $g = 9.81\ \text{m/s}^2$ or $9.81\ \text{N/kg}$
Gravitational Constant	$G = 6.67 \times 10^{-11}\ \text{N•m}^2/\text{kg}^2$
Mass of Earth	$M_e = 5.98 \times 10^{24}\ \text{kg}$
Radius of Earth	$R_e = 6.37 \times 10^{6}\ \text{m}$
Coulomb's Law Constant	$k = 8.99 \times 10^{9}\ \text{N•m}^2/\text{C}^2$
Electron Volt	$1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$
Elementary Charge	$e = 1.60 \times 10^{-19}\ \text{C}$
Index of Refraction of Air	$n = 1.00$
Speed of Light in Vacuum	$c = 3.00 \times 10^{8}\ \text{m/s}$

Atomic Physics

Energy of an Electron in the 1st Bohr Orbit of Hydrogen	$E_1 = -2.18 \times 10^{-18}\ \text{J}$ or $-13.6\ \text{eV}$
Planck's Constant	$h = 6.63 \times 10^{-34}\ \text{J•s}$
Radius of 1st Bohr Orbit of Hydrogen	$r_1 = 5.29 \times 10^{-11}\ \text{m}$
Rydberg's Constant for Hydrogen	$R_H = 1.10 \times 10^{7}/\text{m}$

Particles

	Rest Mass	Charge
Alpha Particle	$m_\alpha = 6.65 \times 10^{-27}\ \text{kg}$	α^{2+}
Electron	$m_e = 9.11 \times 10^{-31}\ \text{kg}$	e^-
Neutron	$m_n = 1.67 \times 10^{-27}\ \text{kg}$	n^0
Proton	$m_p = 1.67 \times 10^{-27}\ \text{kg}$	p^+

Trigonometry and Vectors

$$\sin\theta = \frac{opposite}{hypotenuse}$$

$$\cos\theta = \frac{adjacent}{hypotenuse}$$

$$\tan\theta = \frac{opposite}{adjacent}$$

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

$$c^2 = a^2 + b^2 - 2ab\cos C$$

For any Vector $\vec{R}$

$$R = \sqrt{R_x{}^2 + R_y{}^2}$$

$$\tan\theta = \frac{R_y}{R_x}$$

$$R_x = R\cos\theta$$

$$R_y = R\sin\theta$$

Prefixes Used With SI Units

Prefix	Symbol	Exponential Value	Prefix	Symbol	Exponential Value
pico	p	10^{-12}	tera	T	10^{12}
nano	n	10^{-9}	giga	G	10^{9}
micro	µ	10^{-6}	mega	M	10^{6}
milli	m	10^{-3}	kilo	k	10^{3}
centi	c	10^{-2}	hecto	h	10^{2}
deci	d	10^{-1}	deka	da	10^{1}

EQUATIONS

Kinematics

$$\vec{v}_{\text{ave}} = \frac{\vec{d}}{t}$$

$$\vec{d} = \vec{v}_{\text{f}}t - \frac{1}{2}\vec{a}t^2$$

$$\vec{a} = \frac{\vec{v}_{\text{f}} - \vec{v}_{\text{i}}}{t}$$

$$\vec{d} = \left(\frac{\vec{v}_{\text{f}} + \vec{v}_{\text{i}}}{2}\right)t$$

$$\vec{d} = \vec{v}_{\text{i}}t + \frac{1}{2}\vec{a}t^2$$

$$v_{\text{f}}^2 = v_{\text{i}}^2 + 2ad$$

Dynamics

$$\vec{F} = m\vec{a}$$

$$F_{\text{g}} = \frac{Gm_1m_2}{r^2}$$

$$\vec{F}t = m\Delta\vec{v}$$

$$g = \frac{Gm_1}{r^2}$$

$$\vec{F}_{\text{g}} = m\vec{g}$$

$$F_{\text{c}} = \frac{mv^2}{r}$$

$$F_{\text{f}} = \mu F_{\text{N}}$$

$$F_{\text{c}} = \frac{4\pi^2 mr}{T^2}$$

$$\vec{F}_{\text{s}} = -k\vec{x}$$

Momentum and Energy

$$\vec{p} = m\vec{v}$$

$$E_{\text{k}} = \frac{1}{2}mv^2$$

$$W = Fd$$

$$W = \Delta E = Fd\cos\theta$$

$$E_{\text{p}} = mgh$$

$$P = \frac{W}{t} = \frac{\Delta E}{t}$$

$$E_{\text{p}} = \frac{1}{2}kx^2$$

Waves and Light

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{n_2}{n_1}$$

$$T = 2\pi\sqrt{\frac{l}{g}}$$

$$\lambda = \frac{xd}{nl}$$

$$T = \frac{1}{f}$$

$$\lambda = \frac{d\sin\theta}{n}$$

$$v = f\lambda$$

$$m = \frac{h_{\text{i}}}{h_0} = \frac{-d_{\text{i}}}{d_0}$$

$$\frac{\lambda_1}{2} = l; \quad \frac{\lambda_1}{4} = l$$

$$\frac{1}{f} = \frac{1}{d_0} + \frac{1}{d_{\text{i}}}$$

Atomic Physics

$$hf = E_{\text{k}_{\text{max}}} + W$$

$$\frac{1}{\lambda} = R_{\text{H}}\left(\frac{1}{n_{\text{f}}^2} - \frac{1}{n_{\text{i}}^2}\right)$$

$$W = hf_0$$

$$E_{\text{n}} = \frac{1}{n^2}E_1$$

$$E_{\text{k}_{\text{max}}} = qV_{\text{stop}}$$

$$r_{\text{n}} = n^2 r_1$$

$$E = hf = \frac{hc}{\lambda}$$

$$N = N_0\left(\frac{1}{2}\right)^n$$

Quantum Mechanics and Nuclear Physics

$$E = mc^2$$

$$p = \frac{h}{\lambda}$$

$$p = \frac{hf}{c}; \quad E = pc$$

Electricity and Magnetism

$$F_{\text{e}} = \frac{kq_1q_2}{r^2}$$

$$V = IR$$

$$|\vec{E}| = \frac{kq_1}{r^2}$$

$$P = IV$$

$$\vec{E} = \frac{\vec{F}_{\text{e}}}{q}$$

$$I = \frac{q}{t}$$

$$|\vec{E}| = \frac{V}{d}$$

$$F_{\text{m}} = IlB_{\perp}\text{P}$$

$$V = \frac{\Delta E}{q}$$

$$F_{\text{m}} = qvB_{\perp}$$

$$R = R_1 + R_2 + R_3$$

$$V = lvB_{\perp}$$

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{N_{\text{p}}}{N_{\text{s}}} = \frac{V_{\text{p}}}{V_{\text{s}}} = \frac{I_{\text{s}}}{I_{\text{p}}}$$

$$I_{\text{eff}} = 0.707\, I_{\text{max}}$$

$$V_{\text{eff}} = 0.707\, V_{\text{max}}$$

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